NASA Facts

National Aeronautics and
Space Administration

Dryden Flight Research Center
P.O. Box 273
Edwards, California 93523
AC 805-258-3449
FAX 805-258-3566
pao@dfrc.nasa.gov

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F-15 ACTIVE: Advanced Control Technology for Integrated Vehicles

F-15 ACTIVE in flight, NASA photo EC96 43485 13

Project Summary

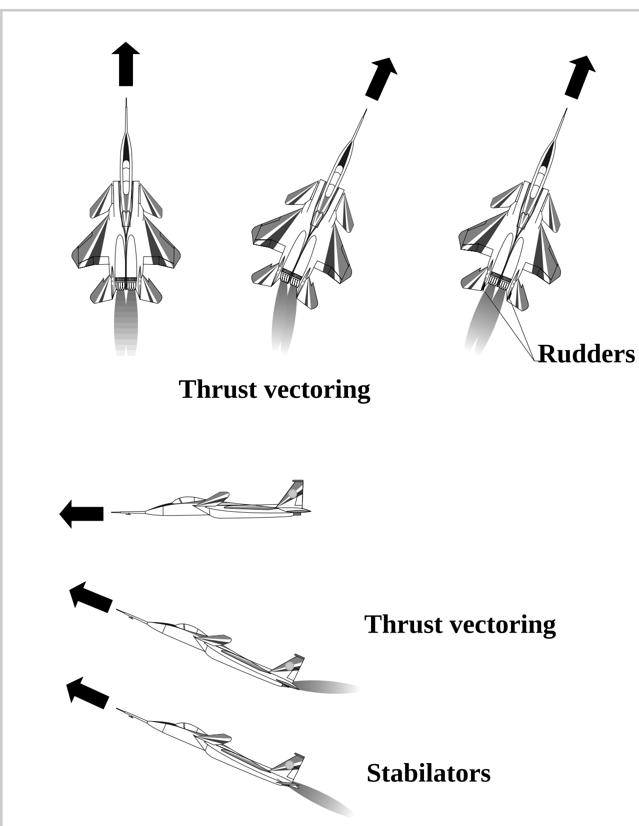
The Advanced Control Technology for Integrated Vehicles—or "ACTIVE"—program at NASA's Dryden Flight Research Center is a multi-year flight research effort to enhance the performance and maneuverability of future civil and military aircraft. For this program, advanced flight control systems and thrust vectoring of engine exhaust have been integrated into a highly-modified F-15 research aircraft. The program is a collaborative effort by NASA, the Air Force Research Laboratory, Pratt & Whitney, and Boeing (formerly McDonnell Douglas) Phantom Works. The ACTIVE program supports the Revolutionary Technology Leaps pillar of NASA's Aeronautics and Space Transportation Technology Enterprise by revolutionizing the way in which aircraft are designed and built by providing the design tools to increase design confidence and cut design time for next-generation aircraft in half.

Aircraft Description & Modifications

The F-15 ACTIVE research aircraft, the first two-seat F-15 built by McDonnell Douglas, was used initially for developmental testing and evaluation. In the mid 1980's, the aircraft was extensively modified for the Air Force's Short Takeoff and Landing Maneuvering Technology Demonstrator (S/MTD) program. Those modifications included equipping the aircraft with a digital fly-by-wire control system, canards (modified F-18 horizontal stabilators) ahead of the wings and two-dimensional thrust-vectoring, thrust-reversing nozzles which could redirect engine exhaust either up or down, giving the aircraft greater pitch control and aerodynamic braking capability.

After being loaned to NASA for the ACTIVE program, the twin-engine F-15 was equipped with a powerful research computer, higher-thrust versions of the Pratt & Whitney F-100 engine and newly developed axisymmetric thrust-vectoring engine exhaust nozzles that are capable of redirecting the engine exhaust in any direction, not just in the pitch (up and down) axis or direction.

Pratt & Whitney's Yaw Balanced Beam Nozzle, Pratt & Whitney photo.



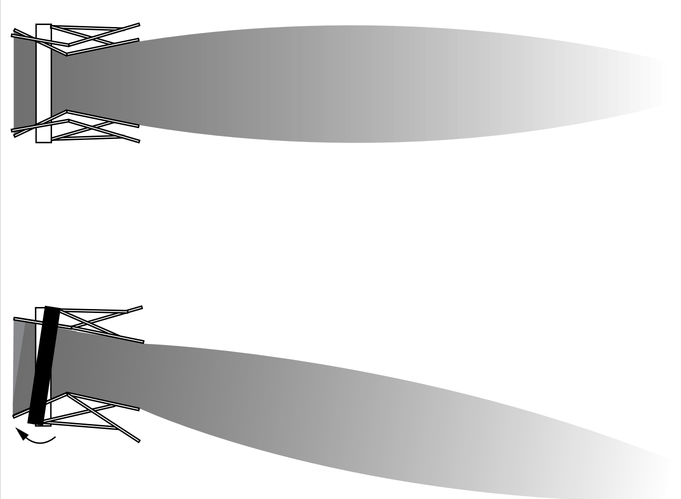
Use of propulsion controls in place of aerodynamic controls.

The new nozzles can deflect—or vector—engine thrust up to 20°off center line, giving the aircraft thrust control in pitch (up and down) and yaw (left and right), or any combination of the two axes. This deflected (vectored) thrust can be used to reduce drag and increase fuel economy or range as compared with conventional aerodynamic controls. The nozzles are a production design that could be incorporated into current or future aircraft.

In addition, an integrated system to control its aerodynamic control surfaces and its engines was installed in the ACTIVE F-15 along with cockpit controls and electronics from the F-15E.

Project Status

Several flight research milestones have been recorded in the ACTIVE program to date. The first supersonic yaw-vectoring flight was flown in early 1996, and pitch and yaw thrust vectoring at speeds up to Mach 2—twice the speed of sound was evaluated during several flights late in the year. On subsequent flights, Dryden research pilots flew the F-15 ACTIVE at angles of attack up to 30° while employing yaw vectoring.“Angle of attack” describes the relationship between the aircraft’s body and wings to its actual flight path.



Thrust vectoring nozzle

An adaptive performance software program was developed and successfully tested. The performance-optimization program installed in the aircraft's flight control computer automatically determines the optimal setting or trim for the thrust-vectoring nozzles and aerodynamic controls to minimize aircraft drag. On the last flight of 1996, the F-15 ACTIVE demonstrated the software's effectiveness by gaining a speed increase of Mach 0.1 with no increase in engine power while in level flight at 30,000 ft altitude and a speed of approximately Mach 1.3.

The F-15 ACTIVE has continued to expand the limits of its thrust-vectoring capabilities during 1997 and 1998, including an experiment which combined thrust vectoring with its regular aerodynamic controls to improve the performance of the F-15E tactical fighter on ground attack missions.

Testbed Experiments

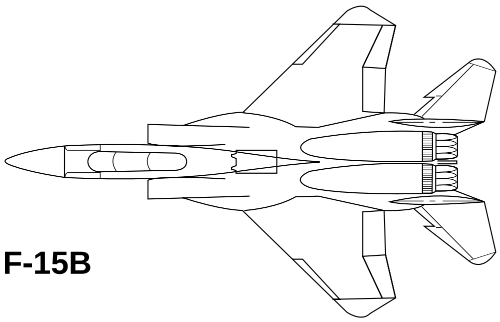
The F-15 ACTIVE's unique propulsion control systems and flight test instrumentation have allowed it to be used as a testbed for several research experiments unrelated to the ACTIVE program. Each experiment contributed to goals which will benefit Global Civil Aviation, another one of the three pillars of NASA's Aeronautics and Space Transportation Technology Enterprise.

HIGH STABILITY ENGINE CONTROL (HISTEC)—This experiment, developed and managed by NASA's Lewis Research Center, evaluated a computerized system that can sense and respond to high levels of engine inlet airflow turbulence to prevent sudden in-flight engine compressor stalls and potential engine failures. The system used a high-speed processor to process the airflow data coming from sensors on the left engine, and it in turn directed the aircraft's engine control computer to automatically command engine trim changes to accommodate for changing turbulence levels. The system can enhance engine stability when the inlet airflow is turbulent, and increase engine performance when the airflow is stable or smooth. Approximately one dozen flights were flown in the summer of 1997 to validate the HISTEC concept. The project contributed to the Affordable Air Travel goal of significantly reducing the cost of air travel, and the Safety goal to reduce the aircraft accident rate.

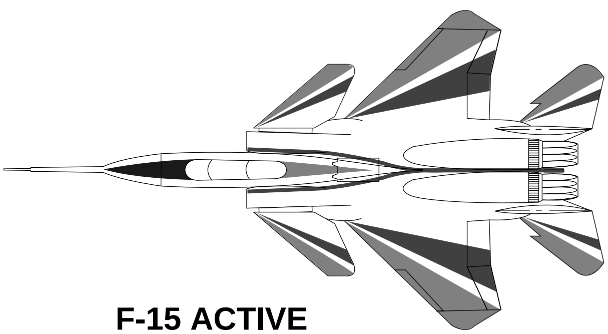
HIGH-SPEED RESEARCH ACOUSTICS—The unique ability of the thrust-vectoring nozzles to change the "area ratio"—the difference in the geometric area—between the nozzles' throat and exit led to the F-15 ACTIVE being used for research in the fall of 1997 on how to reduce perceived engine noise. Conducted on behalf of Langley Research Center's High-Speed Research program, this flight experiment focused on validating noise prediction data that could be applied to reducing noise generated during takeoffs and landings of the High Speed Civil Transport, the proposed second-generation American supersonic jetliner. By fully expanding the nozzles' exit area, noise generated by the hot jet exhaust entering the surrounding cooler air is reduced. The acoustics research involved flying the F-15 ACTIVE in precise patterns over an array of 30 microphones spread out over more than a mile along the northeast side of Rogers Dry Lake. The project contributed to the Environmental Compatibility goal of significantly reducing the perceived noise levels of future aircraft.

INTELLIGENT FLIGHT CONTROL—This experiment, planned for flight testing in late 1998-early 1999, is intended to assist development of advanced "neural network" flight control computer technology that would allow aircraft control systems to adapt to unforeseen changes in aircraft operating conditions, such as sudden equipment failures or battle damage, by directing the aircraft's remaining functional control systems to compensate for the failure or damage. Successful development and validation of the Intelligent Flight Control concept will contribute to NASA's Safety goal by allowing safe return of aircraft that otherwise might be uncontrollable after sustaining damage or major system failures.

NASA Dryden's two F-15B aircraft fly in tight formation during a research mission. The F-15 ACTIVE, right, is distinguished by the canards mounted outside the engine air inlets and by its distinctive red, white, and blue color scheme. NASA photo EC96 43656-1

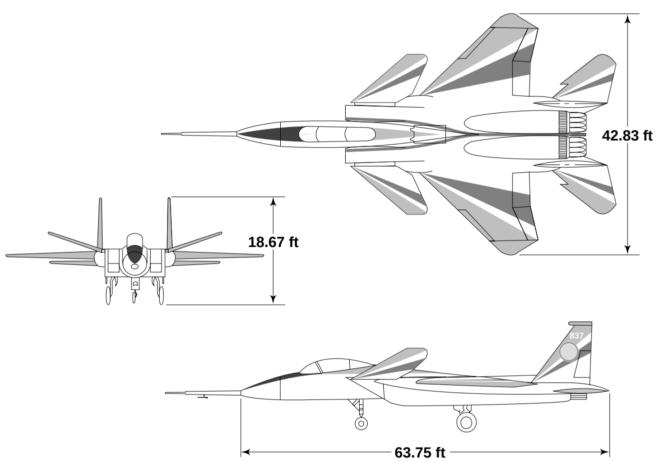


F-15B



F-15 ACTIVE

The F-15 ACTIVE is distinguished by the canards mounted outside the engine air inlets.



Three view of F-15 ACTIVE.

Technology Commercialization

The overall goal of the ACTIVE program is to help develop technology for the next generation of high-performance civil and military aircraft, as well as significantly cut the time spent in design by reducing complexity. Applying new integrated flight/propulsion control technology can lead to development of revolutionary new designs which will be lighter, less complex, less costly, and with greatly improved performance as conventional aerodynamic controls and their systems are reduced or eliminated.

Aircraft Statistics

The F-15 is a versatile aircraft, employed by the U.S. Air Force as its premier air-superiority fighter/interceptor aircraft as well as its long-range all-weather strike fighter. It is an ideal aircraft for the ACTIVE research role.

Designation: F-15B, originally TF-15A
Manufacturer: McDonnell Douglas, 1972
Owner: United States Air Force
USAF Registration: 71-290
NASA registration: (tail number) 837
NASA role: Integrated controls/propulsion research
Maximum altitude: 60,000 ft
Max. speed: Mach 2.0
Engines: Two Pratt & Whitney F100-PW-229
Max. thrust: 29,000 lb in full afterburner each
Weight: 47,000 lb takeoff; 35,000 lbs empty
Fuel capacity: 11,520 lb (approx. 1,700 gal)
Wingspan: 42.8 ft
Length: 63.7 ft, excluding flight test nose boom
Horizontal tail span: 28.2 ft
Canard span: 25.6 ft